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Session L39: Turbulence: Geophysical Fluid Dynamics
8:00 AM–10:36 AM, Monday, November 25, 2024
Room: 355 E

Chair: Dhiraj Kumar Singh, University of Utah

Abstract: L39.00009 : Detecting Coherent Turbulence Structures in Planetary Boundary Layers via Koopman Mode Decomposition and Data-Driven Methods*
9:44 AM–9:57 AM

Abstract

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The planetary boundary layer (PBL) exhibits highly nonlinear dynamics, which stems from its turbulent and chaotic nature. While many studies attempted to characterize coherent turbulence structures in PBLs, there is currently no overarching data-driven method for detecting such structures under different PBL regimes. This study aims to bridge this gap by using Koopman mode decomposition (KMD), unsupervised clustering, and large eddy simulations (LES). To this end, eight LESs of convective, neutral, and unsteady PBLs are conducted. The LES results show that increasing the buoyancy-to-shear ratio alters roll vortices to convective cells in PBLs. KMD was shown to detect non-trivial dynamical modes of such PBLs. Using timescale and quadrant analyses, we attributed these modes to pressure gradient, Coriolis, and buoyancy forces. It is found that only ~5% of the Koopman modes can reconstruct the primary PBL flow field compared to the actual LES data even under unsteady conditions. Furthermore, we combined convolutional neural networks with K-means clustering to efficiently classify Koopman modes according to their intrinsic dynamics. This study offers new insights into the PBL dynamics and presents a data-driven framework for characterizing complex spatiotemporal turbulence structures.

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